



RESEARCH ARTICLE

## DESIGN AND IMPLEMENTATION OF FRAMEWORK FOR SMART CITY USING LORA TECHNOLOGY

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### ABSTRACT

This paper explains the proposed architecture for a smart city using LoRa Technology. The framework is designed and implemented with two applications by using LoRa modules and LoRa gateway. The data from the end devices is reached to cloud via LoRa gateway; in this process end devices use only LoRa communication for sending data. The first application is monitoring environmental parameters like air quality and carbon monoxide content. This is implemented by creating a device with Dragino LoRa module and required sensors. The device will be sending the values to LoRa gateway by using LoRa communication. From Gateway the data will be sent to cloud where the administration can notice the heavily polluted regions and take necessary action. The second application is about providing safety for women and children. For this a wearable device is designed with Dragino LoRa GPS module. This device can be used to notify the location of the person in an emergency situation and can also notify if the person is out of the boundaries provided.

**Keywords:** Smart City, LoRa, LoRa WAN, Long Range, Low Power.

### 1. INTRODUCTION

In today's world wireless sensor networks are playing major role in the processing of huge quantity of data. To accomplish the vision of a Smart city many wireless sensor networks are deployed in various domains with a variety of applications; so, a large quantity of data is being produced every day. The innovative processes and procedures are in need of successful data administration and analysis to produce information which is useful for managing the utilization of resources wisely and dynamically. To connect objects, long range and low power communication technology is needed; therefore, LoRa WAN technology has been developed.

Smart City is the standard in the Information and Communication Technology (ICT) era which provides the framework to the society to get administration carried on in many fields effortlessly, and facilitates the supervision and control on the assets in a city [1] for the administrators. The authorities in the smart city are utilizing ICT to detect, examine and coordinate the data in managing the urban communities [2]. As the populaces of urban communities are developing, and the limits of urban communities extending, the idea of the smart city is picking up energy on the motivation of neighbourhood governments, as it can be viewed as a vital intention to change the conventional urban areas. The end goal is to

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enhance financial growth, mechanical advance and ecological advance and maintainability [3].

IoT technology is an environment that transfers data through Internet in real time to attach the sensor to the object. Until now, the devices connected to the Internet needed some adjustment by humans to exchange the data. But IoT enables to exchange the data between humans and objects and among objects connected with Cloud and big data technology, without the adjustment. Low Power Wide Area Network (LPWAN) technology was suggested to transfer object's data efficiently. It is a mobile radio communication network and a low power broadband convergence network for devices of IoT.

If near field communication technologies such as Bluetooth and Zigbee are used for any smart application, the administrator needs to undergo a complex procedure for gateway and end devices communication. But LPWAN solves this problem and connects directly. This technology is useful in outdoor application area where a number of devices are required. LPWAN technology has been through the standardization process as it becomes commercialized like other technologies in ICT area.

LoRa is one such LPWAN protocol which targets two types of devices such as battery powered devices with limited energy and the devices which only transmit a small number of bytes at a particular time [4]. For many smart sensing applications like health monitoring, smart metering, environment monitoring and also for industrial applications, LoRa becomes the most prominent choice because of its great features of low power and long range.

For low power wireless IoT communication, many communication technologies are evolved and implemented. As mentioned above, the available technologies can be arranged in two categories:

- Low power local area networks with under 1km territory: In this class IEEE 802.15.4, IEEE P802.15.4, Bluetooth/LE, etc. are included. These are relevant straight forward, in the short-run individual region systems, in the body region systems; or, if sorted out in a work topology, likewise in the bigger zones.
- Low-power wide area networks, with a larger than 1km range: these are basically low-control

forms of cell systems, with every "phone" covering a large number of end-gadgets. This class incorporates LoRa WAN, and additional conventions; for example, Sigfox, DASH7 and so on [5].

## 2. LORA AND LORAWAN

Long Range Radio Communication (LoRa) is a wireless modulation or physical layer developed to build the long range communication links. Frequency shifting keying (FSK) modulation is utilized by different remote frameworks as the physical layer, since it is an extremely capable balance for getting low power. Base adjustment for LoRa is Chirp spread spectrum; it has similar low power feature as FSK. However, it apparently increases the communication range [6].

LoRa is one of the most competent wide-area IoT technologies proposed by Semtech and further endorsed by the LoRa Alliance. LoRa's success depends on its adaptive data rate chirp modulation technology which provides flexible long-range communication with low power consumption and low cost design.

LoRa WAN, based on Semtech's LoRa wireless RF IC, is the open MAC layer protocol, defined and standardized by the LoRa Alliance. It operates in unlicensed spectrum, enables long-range, bidirectional communication and is deployed in a star-of-stars network architecture whereby the end nodes are not connected with a precise gateway; but, they transmit the data to multiple gateways within their range. Tens of thousands of sensor nodes are supported by each gateway separately. LoRa WAN data rates are scalable and follow an adaptive data rate algorithm to optimize the power consumption and the network capacity [7].

### 2.1 Sub GHz Advantages

The key enabler for the IoT devices are Low-power wireless networks, but familiar networks such as Zigbee, Wifi, Cellular, Bluetooth are not fulfilling the requirements of the long range and battery life together; so, to overcome this new Sub-GHz specifications, these low power networks are used by LoRa WAN.

High information rates are accomplished by high recurrence alternatives; however, they have restricted range at adequate power levels. Low

recurrence operation is the favoured approach for the power constrained plans that need an expanded range. Low power is requisite to keep up a precise link budget at the indicated range when the recurrence is lower.

Lower data rates are possible by lower frequency transmissions; but, the applications related to IoT are not often present major throughput requirements. One more advantage using the lower data rates is the reduced error rates which influence the sensitivity requirements of the receiver [8].

By utilizing sub-GHz interchanges, the prerequisites for range, power, and information rate required by most IoT applications can be met with. These key parameters can be influenced by the decision of the modulation technique utilized for information encoding.

## 2.2 Modulation Method

Spread Spectrum Modulation techniques are utilized for quite a long time to enhance insusceptibility to noise or interfering signals. In the traditional Direct Sequence Spread Spectrum (DSSS) systems, code sequence is used to change the phase of the carrier signal. In this process, the chip sequence which is also known as the spreading code is multiplied by the wanted data signal. The occurrence of chip sequence is faster than the data signal rate and spreads beyond the original bandwidth occupied by data signal.

On the receiver side, the required data signal is achieved by re-multiplying with a locally generated replica of the spreading sequence. This multiplication process in the receiver successfully compresses the spread signal back to its original unspread bandwidth.

DSSS is generally used in many data communication applications. But there are some challenges that exist for low-cost or power-constrained devices and networks.

Semtech's LoRa modulation addresses all of the issues associated with DSSS systems to provide a low cost, low-power, yet above all robust alternative to the traditional spread-spectrum communications techniques.

The advantages of the spread spectrum noise immunity are brought by LoRa and advanced

as a special spread spectrum modulation technique which improves the plan necessities. LoRa modulation is based on a frequency modulated "chirp" signal that can be generated with a reasonably uncomplicated fractional-N Phase-Locked Loop (PLL) [9].

LoRa transmission is started by issuing a preamble including a progression of chirps (Figure 1a). The transmission proceeds with a progression of chirps that encode information basically as recurrence hops in the chirp signal, like the utilization of various recurrence tones to encode the information in M-ary FSK (Figure 1b).

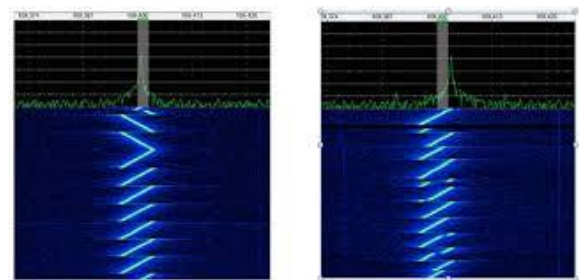


Figure 1a. LoRa transmission Figure 1b Payload of a transmission

This waterfall view demonstrates the repeated chirps utilized as part of the LoRa transmission (Figure 1a) and the chirps encoding the payload of a transmission (Figure 1b).

On the collector side, gathering of a message stream is started by a PLL which can bolt onto the Preamble. Due to the varied pattern of the chirps, a LoRa modem can recognize signals as low as 20 dB beneath the noise floor. LoRa innovation empowers strong availability over long ranges with -148 dBm sensitivity. LoRa modem can serve huge quantities of IoT gadgets working all the while as it gets a few distinct transmissions, each contrasting just in chirp rates, simultaneously.

## 2.3 Key Properties of LoRa Modulation

### 2.3.1 Scalable Bandwidth

LoRa modulation is both data transmission and recurrence adaptable. It can be utilized for both narrowband recurrence bouncing and wideband direct succession applications. Not at all like existing narrowband or wideband regulation plans, LoRa can be effectively adjusted for either method of operation with just a couple of basic configuration enrolment changes.

### 2.3.2 Consistent Envelop/Low Power

Like FSK, LoRa is a steady envelope modulation technique which implies that a similar minimal effort and low-control high-effectiveness PA stages can be reutilized without any change. What is more, because of the processing gain related to LoRa, the output energy of the transmitter can be diminished and contrasted with a customary FSK interface while keeping up the same or better link budget.

### 2.3.3 High Robustness

Owing to the high BT item ( $BT > 1$ ) and its non concurrent nature, a LoRa signal is exceptionally impervious to both in-band and out-of-band obstruction components. Since the LoRa image period can be longer than the normal brief length burst of quick jumping FHSS frameworks, it accommodates incredible invulnerability to beat AM impedance systems; and, commonplace recipient out-of-channel selectivity figures of 90 dB and co-channel dismissal of superior to anything 20 dB can be acquired. This thinks about to commonly 50 dB for nearby and interchange channel dismissal and 6 dB co-channel dismissals for FSK regulation.

### 2.3.4 Multipath/Blurring Resistant

The chirp signal is generally broadband; and in this manner, LoRa offers resistance to multipath and blurring, making it perfect for use in both the urban and rural situations, where the two systems overwhelm.

### 2.3.5 Doppler Resistant

Doppler move causes a little recurrence move in the LoRa pulse which presents a moderately insignificant move in the time axis of the baseband signal. This recurrence-balance-resilience mitigates the necessity for tight-resistance-reference clock sources. LoRa is perfect for mobile data communications; for example, remote tire-pressure checking frameworks, drive-by applications, toll corner, tag readers and trackside interchanges for railroad foundation.

### 2.3.6 Long Range Capability

For a settled output power and throughput, the connection spending plan of LoRa surpasses that of customary FSK. At the point when brought into conjunction with the demonstrated heartiness to

impedance and blurring instruments, this change in interface- spending plan can promptly mean x4 and past improvement in run.

### 2.3.7 Upgraded Network Capacity

Semtech LoRa modulation utilizes orthogonal spreading factors which empowers various spread signs to be transmitted in the meantime and on a similar channel, without negligible degradation in the RX affectability. Regulated signs at various spreading factors show up as noise to the objective beneficiary and can be dealt with in that capacity.

### 2.3.8 Ranging/Localization

A characteristic property of LoRa is the capacity to directly separate the recurrence and time mistakes. LoRa is the perfect balance for radar applications and, along these lines in a perfect world, suited for ranging and localization applications, for example, in the real time location services.

## 3. SYSTEM DESIGN

The total system is divided into three modules as shown in the figure below:

1. Client Module
2. Gateway Module
3. Cloud Module

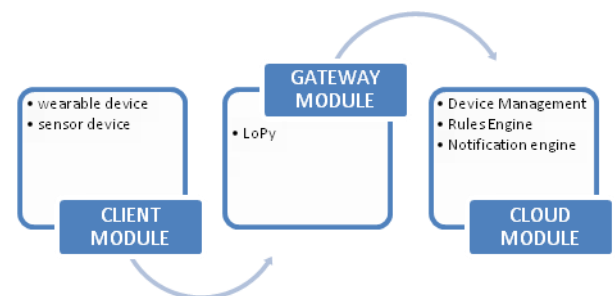


Figure 2. System Design

### 3.1 Client Module

In the Client Module, two devices are designed for two different applications. The first is a wearable device for providing women and children's safety; this is designed using Dragino LoRa GPS shield mounted on arduino board and connected to switch. This device will send the

location details of end user to the gateway, using LoRa Communication.

The second is a sensor device which is designed using Dragino LoRa shield, mounted on arduino board and connected with two sensors like air quality sensor MQ135 and carbon monoxide sensorMQ7. This device will be sending the sensor values to gateway to monitor the environmental parameters.

### 3.2 Gateway Module

In this module LoPy is used as gateway for communication between the Client Module and the Cloud Module. The information from the end devices presented at the Client Module is transferred to web server in the Cloud Module through LoRa Gateway.

With LoRa, Wifi and BLE, LoPy is the main triple conveyor Micro Python, empowered with smaller scale controller available today; it is the ideal undertaking grade IoT stage for associated Things. With the most recent Espresso chipset, the LoPy offers an ideal mix of energy, amicability and adaptability. It interfaces things all over the place.

LoPy gateway is capable of bidirectional communication and also has the capability to work within the range of 45 kms. Basically, this gateway has three types of communication technologies like Bluetooth, WiFi and LoRa. In this system, two technologies, LoRa communication and WiFi communication, are used.

Lora communication comes into force while receiving the data from the Client Modules to the gateway; and, WiFi communication comes into force when the received data is to be uploaded to the cloud. HTTP protocol is used for the data communication between gateway and cloud.

- LoPy device should be located as per the requirement.
- Receiving data from the Client Modules through LoRa Communication.
- Sending the data to cloud using HTTP.

### 3.3 Cloud Module

The cloud module in this system explains the webpage designed for the user services and maintenance of the data. This Cloud Module will function in two ways, the first one is the front end

application of the webpage and the other one is database.

At the frontend, the system will take the user details from the registration and creates a user profile in the database with unique user key. Later on, it will create and maintain the devices data, according to the user's specification.

At the backend, the data received from te gateway is stored according to the specific user and their devices. And, the data is visualized under the device data in user profiles.

#### 3.3.1 Device Management

Device management will allow the authenticated users to create their own devices as per the requirement. Once the users are logged into their accounts, they can create any number of devices of different types. For each device there is a unique device key generated which will be useful in sending the data to the server.

The user can create devices by using specific name to each device and selecting the type of device. Each device can have various fields based on the requirement. Data visualization is available for each device.

#### 3.3.2 Rules Engine

The Rules Engine is a service for the end user to modify rules without taking help of the programmer. When a change occurs, the engine will estimate the change's effect on the other rules in the system and notify the user if there is a variance. In this webpage an option is given to set the threshold values for each field of the device. These values are set by the end user depending on the device operation and these can be changed any time. These threshold values are helpful of generating notifications to the user about the device to take necessary actions.

#### 3.3.3 Notification Engine

Notification Engine is designed to send notifications to the registered users according to the preferences of the user. The user can register any mobile number here to get the notifications about the device. Whenever the values of the device exceed the threshold level, the user gets notified about the same for necessary action.

## 4.RESULTS AND APPLICATIONS

### 4.1 Monitoring Environmental Parameters

Air pollution is in charge of an extensive variety of restorative conditions. The current air-contamination-observing frameworks comprise of costly stations that measure a restricted scope of parameters. On account of the high cost of these stations, it is not functional for urban communities to quantify the air quality over and across the board territory in detail. Accordingly, the urban areas do not regularly have the kind of measuring framework set up to actualize better air quality projects.

The urban areas can better quantify the quality and give the sort of information important to drive the change for their citizens by actualizing an air-contamination-checking arrangement-involved sensors and gateways installed with LoRa Technology and a clever low-control and a wide range network in the light of the LoRaWAN convention.

In this module two sensors are used, MQ135 for air quality measurement and MQ7 for carbon monoxide detection. The working of this module is as below:

- Air observing sensors implanted with LoRa Technology are put all through the city.
- Sensors send occasional estimations of air quality information to a gateway.
- Gateway sends the data to arrange where the information is broken down by an application server which can distinguish the zones of concern and give proposals.
- Application Server gives the data with regard to the air quality levels all through the city, including alarms and contamination designs, by means of PC or portable gadget. Moreover, it can likewise gauge the adequacy of air quality projects, with the goal that the urban communities can imitate programs in the other issue zones.

#### 4.1.1 Indoor Air Quality

When the sensor device is placed indoor as in a room where no gases are present, the quality of air is in the range of 300 to 500 ppm. The data graph of this is shown in Figure 3.

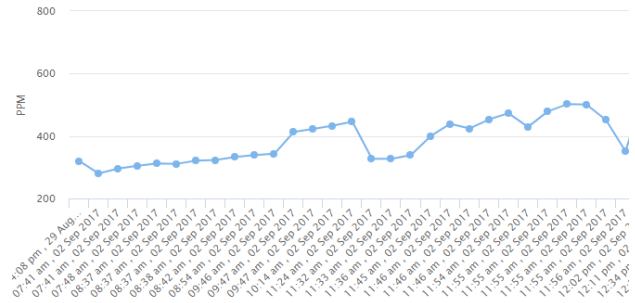


Figure 3. Data Graph of Indoor Air Quality.

#### 4.1.2 Outdoor Air Quality

When the sensor device is moved outdoor, the quality of air levels is moved to 450 to 700 ppm due to the presence of some gases. The Data graph for outdoor air quality can be seen in Figure 4.



Figure 4. Data Graph of Outdoor Air Quality

#### 4.1.3 Heavily Polluted Region

In this case when the sensor is placed in a heavily polluted area, or when the sensor is intentionally subjected to heavy gases like alcohol, ammonia and smoke, the air quality decreases; and, the range of pollution is between 650 and 1000 ppm which is very harmful. The Data graph for the air quality in the polluted region is shown in below Figure 5.



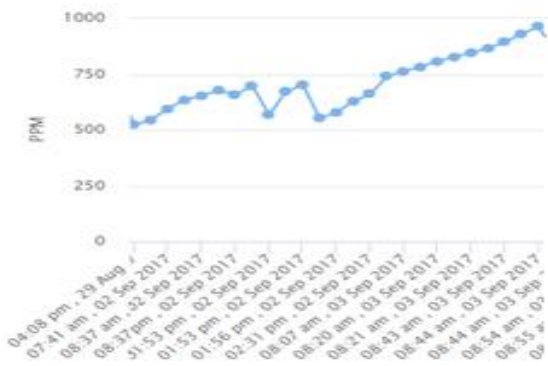


Figure 5. Data Graph of Air Quality in Heavily Polluted Region

In all above graphs, on x axis time period and on y axis the ppm values of air quality are represented. By observing the above graphs we can notice that the quality of air is decreasing over a time period.

#### 4.1.4 Detection of Carbon Monoxide

MQ7 sensor is used to detect the carbon monoxide content in the air. All the gas sensors work with the same principle and give the output in PPMs. The normal range of carbon monoxide content in air is 0 to 10 ppm. In the natural fresh air, the CO content is 0.1 ppm; in the home atmosphere it varies from 0.5 to 5 ppm; and in vehicular emissions, it ranges from 5 to 15 ppm.

The application for detecting the content of carbon monoxide in two aspects has been tested. Firstly, the sensor is placed in a room where normal air is presented; the content of carbon monoxide in this area is represented with the data graph which is shown in Figure 6.



Figure 6. Data Graph of Carbon monoxide Content

To monitor the higher contents of carbon monoxide, the sensor is moved to the area where vehicular emissions are high. The content of carbon monoxide in this region is 5-10 ppm. It is shown in Figure 7.

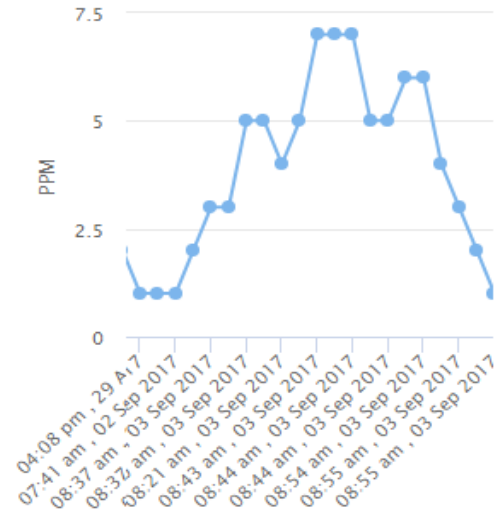


Figure 7. Data Graph of High Carbon monoxide Content

#### 4.2 Women and Child Safety

Safety is the primary factor in our daily life; so, the people who are not potential enough for self defence can be given the strength and option for protecting themselves by implementing a wearable device.

The wearable device consists of Dragino Lora module with GPS and a push button. A boundary for the device can be set; whenever the person with that device is out of the boundary, the alert notification is sent by server with the location. Within the boundary too, if the button is pressed in an emergency situation, it will be notified. The notifications are shown in Figure 8.

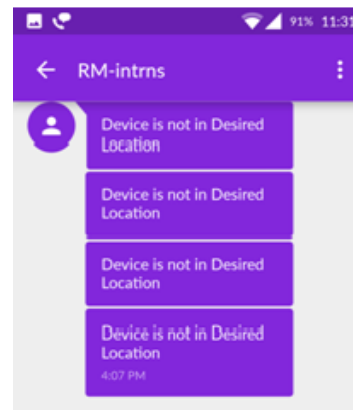


Figure 8. Mobile Notifications

In this module, Dragino LoRa GPS shield is mounted on Arduino board and the switch button is connected to it. The location details such as latitude

and longitude are detected by LoRa GPS shield and are transmitted to LoRa gateway.

Switch button is provided for emergency situations; if a person with the device faces any emergency situation, s/he can press the switch to notify the same to the person concerned.

## 5 CONCLUSION

For the welfare of the society, a framework has been designed to be utilized by upcoming smart cities to make the city most safe and progressive in all respects. In this project, two applications have been implemented using LoRa technology which makes this project stand alone with its specialized advantages such as low power, long range, long battery lifetime, simplicity of arrangement and low cost.

Air quality is the important factor for safe life of human beings. So, it has been decided to create a prototype for monitoring the pollution levels in a city, using LoRa technology. In this system end user devices are designed with LoRa modules and sensors; these devices can send the data to the gateway with Lora communication. This data will be transferred to the cloud for further analysis and actions. Two sensors have been used to detect the quality of air and content of carbon monoxide; by monitoring these sensor readings, the users could be notified about the pollution levels which alert them to be careful and work on for reducing the pollution level. Considering the work environment and busy schedules of the life of citizens, a wearable device has been created for providing safety to the women, children and elderly people. The device is created with LoRa GPS module along with a switch button. The functionality of the device is to notify the user whenever the device is moved out of the specified boundary or when the switch button is pressed in emergency situation. This device helps to keep track of the persons in need of help and know about their safety without striving hard.

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## APPENDIX

LoRa – Long Range.

LoRa WAN – Long Range Wide Area Network.

LPWAN – Low Power Wide Area Network.

IoT – Internet of Things.

ICT - Information and Communication Technology.

FSK – Frequency Shift Keying.

GPS – Global Positioning System.

HTTP – Hyper Text Transfer Protocol.

PPM – Parts Per Million.